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Short communication

The beginnings of ecological engineering

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Howard T. Odum generated more ideas per minute than anyone I ever met, and I am sure all who encountered him had to be similarly impressed. When he wanted to learn new fields, he once told me, he immersed himself in its literature, attended seminars, and talked with experts in those areas. One of those areas of interest was ecological engineering, and he eventually defined ecological engineering as "environmental manipulations by man using small amounts of supplementary energy to control systems in which the main energy drives are still coming from natural sources" (Odum et al., 1963). Undoubtedly one of the individuals who influenced him to consider this area was Earnest F. Gloyna, then Professor of Civil Engineering at The University of Texas at Austin and head of the Environmental Health Engineering program in that department. Gloyna later served as Dean of the College of Engineering (1970–1988) and recently retired.

Earnest studied Sanitary Engineering under Abel Wohlman at Johns Hopkins University in the 1950s. Sanitary engineering was an engineering field that in the late 1800s had begun finding ways to use natural decomposition processes to treat municipal and industrial wastewaters in large engineered systems. Biological treatment systems had been designed and installed at many major cities throughout the country, but little was known of the kinetics involved, which clearly required knowledge beyond sanitary engineering of that time. Earnest's interests broadened beyond sanitary engineering so much that he minored in chemistry and in microbiology and had some exposure to marine science through his association with Charles Wren, who had a Ph.D. in Marine Biology and an M.S. in Sanitary Engineering, Don Pritchard, well known for his work in physical estuarine processes, and Dayton Carrot, a physical chemist (Gloyna, 2002). Earnest's major career work was researching stabilization ponds for wastewater treatment and developing design criteria for them, and he is internationally known for his work in this field.

As a faculty member at the University of Texas, Austin, Odum had established good funding with the Atomic Energy Commission and the Public Health Service in the 1950s and 1960s, but it was clear that sanitary engineering was broadening to encompass environmental issues and ecology. The basis for waste treatment design began to be focused on protecting aquatic life in receiving waters, and sanitary engineers needed to understand these new areas to make rational and sound decisions about waste treatment. When the Public Health Service awarded grants to the University during that time, it pressured Earnest to expand his faculty to include ecologists, chemists, and microbiologists. To achieve immediate results, Earnest responded by sending engineering students to take microbiology, chemistry, biology, and marine science courses. The marine science teaching program was primarily at the Marine Science Institute at Port Aransas where H.T. was Director. Earnest went to Port Aransas with the engineering students, and he and H.T. had many conversations about pond ecosystems and stabiliza-

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tion ponds, physical, chemical, and biological kinetics in those systems, and mathematical representation of natural systems including the analog computer that Earnest used to represent the dissolved oxygen sag curve below waste discharge outfalls. They also discussed the design of ponds to be constructed at the Institute, which would become mesocosms, the ponds described in Odum et al. (1963; Gloyna, 2002). It was also during this time (1962) that B.J. Copeland began working for H.T. after completing his Ph.D. at Oklahoma State University and measuring primary productivity in oil refinery stabilization ponds. Copeland and H.T. had met in 1959, just after Copeland entered graduate school, and his collaboration with H.T. as well as with Earnest and me continued for many years.

H.T. and his students, primarily Robert Beyers, whose dissertation focused on the metabolism of 12 microcosms (Beyers, 1962), had been investigating the use of microcosms in the laboratory to represent natural systems, for several years. As was stated in Odum et al. (1963), experiments with these small microcosms had "been useful in showing some of the abstract general patterns of succession, climax, population structure, and biogeochemical cycling that are observed in larger natural ecosystems". They stated that "a logical continuation was the culture of somewhat larger experimental ecosystems in concrete tanks so that some of the larger scale processes might be included such as larger animals, larger genetic reservoirs, water current systems, natural lighting fields, larger geochemical reservoirs, and sea-air exchanges" and "attempts to culture some marine ecosystems in ponds are also experiments in ecological engineering of new systems because of such special conditions as pumped circulation, tank walls, constant salinity, and diminished immigration from larger population reservoirs". Three types of natural ecosystems were to be replicated in the ponds constructed at the Institute: (1) low salinity, turbid, plankton-based bay system containing oyster bars typical of Copano, San Antonio, and Matagorda Bays; (2) shallow, grassy bottom systems such as Redfish and Aransas Bays; and (3) blue-green algal mat systems carpeting the shallow-water flats in the Laguna Madre system often under hypersaline conditions. The first plankton-reef pond was improvised from plastic sheeting in July 1960, followed by a concrete grass pond in spring 1961 and triplicate concrete reef ponds in fall 1961, and small concrete ponds for the blue-green algal mats in spring 1962. I carried out the studies on the blue-green algal mats in summer 1962 at Port Aransas, which included metabolism and redox potential studies in the outdoor concrete ponds as well as in small microcosms in the laboratory and analog computer simulations of those systems. Results indicated that "some general aspects of photosynthesis, community respiration, and organismal dominance were similar to those of the bay prototypes", and we concluded that "some similarity of processes and concentration levels maintained in these artificial ecosystems may justify their use for controlled experimental study of the bays" (Odum et al., 1963).

The photoelectric ecosystem became another kind of ecological engineering. Copeland (Boynton, 2002) describes how he and H.T. in 1960 took blue-green algal mat Copeland had collected in Baffin Bay to a NASA scientist at Brooks Army Base in San Antonio to show him how such ecosystems could provide energy to run motors, produce food and oxygen, and recycle wastes. The first extensive microcosm work on blue-green algae mats took place in summer 1962 in Port Aransas with my work on these systems. Subsequent work on the mats as photoelectric ecosystems was done on the main campus in Austin in fall 1962 and spring 1963. Finger bowl as well as test-tube-sized microcosms were used, and metabolism as well as electrochemical potential between the upper oxidized layer of the mat and the lower, reduced layer were measured. We found that the open-circuit potential across the blue-green mat was about 0.43 V, and it represented the reversible free energy momentarily available. The manuscript for the Science article was submitted in October 1963 and published the following January (Armstrong and Odum, 1964).

I first met H.T. at a Texas Academy of Science meeting being held at Southern Methodist University (SMU) in Dallas, TX in the spring of 1958. I was a high school senior interested in marine biology, and a math teacher of mine took me to that meeting to introduce me to H.T. We had a brief conversation before he hurried to hear a paper, but in the brief time we talked and he invited me to come to Port Aransas to work as a Laboratory Assistant that summer. It was my good fortune to do so, to see someone so enthusiastic about teaching and estuaries that he would cry "the blood of the ecosystem!" as he bounded into Redfish Bay ahead of his astonished class, someone so fearless that he would say “the water isn’t deep” if he missed the rows of railroad ties on the causeway to Port Aransas going 60 mph, and someone so caring that he spent significant time out of his busy schedule with each of us. When H.T. left the University of Texas to go to Puerto Rico to work in the rain forest, I had to abandon my plans to complete a Ph.D. under him. Instead, I completed an MA on the Hill reaction with Jack Myers, who was kind enough to take me. Fortunately, however, Earnest and H.T. had obtained a new Public Health Service Training Grant in which students from natural science disciplines were supported while taking courses in engineering, and, once I finished the MA supported by that program, I began my Ph.D. in environmental engineering under Earnest’s supervision and have been in engineering since.

Each of us is affected over our career by a handful of key individuals who affected our lives and careers in dramatic, life-changing ways. H.T. Odum and Earnest F. Gloyna have been two of those individuals in my life, and my life has been richer because of them.

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